

MINE CHARCOAL DEPOSITS: METHODS AND STRATEGIES.

THE MEDIEVAL FURNEL SILVER MINES IN THE HAUTES-ALPES (FRANCE)

VANESSA PY

MMSH, Laboratoire d'Archéologie Médiévale Méditerranéenne, UMR 6572 CNRS
Université de Provence - Aix-Marseille I
5 rue du Château de l'Horloge B.P. 647 F-13094 Aix-en-Provence cedex 2 (France)
py@mmsh.univ-aix.fr

ABSTRACT: The medieval Fournel silver mines in the Hautes-Alpes (France) are an original archaeological cadre for anthracological study. Massive use of fire for breaking down the hard quartzite bedrock developed working strategies which conditioned the architecture of the workings, operational dynamics, morphology of wastes and their management (storing, backfill). These wastes hold large quantities of charcoal, the ultimate traces of the thousands of fires which opened up exploitation of the silver galena (lead sulphur with 0.15% silver). The awkwardness of the archaeological context and the size of backfill conditioned creation of an adapted sampling protocol. Study of these deposits, combined with archaeological analysis of the workings and a sedimentological approach to backfill, has lead to reconstitution of the area where fuel was obtained for the mines. First results allow interpretation in fuel management and environmental adaptation. This communication examines the preliminary studies carried out during a Master's degree thesis on forests and proto-industry in the High Durance valley during the Middle Ages and during scheduled archaeological excavations.

KEY WORDS: mining, fire-setting, techniques, fuel management, charcoal, anatomical signatures

RÉSUMÉ: Les mines médiévales du Fournel dans les Hautes-Alpes (France) constituent un cadre archéologique original pour une étude anthracologique. L'utilisation massive du feu pour attaquer la roche encaissante particulièrement dure (quartzites) a généré des stratégies d'exploitation qui conditionnent l'architecture des ouvrages, la dynamique opératoire, la morphologie des déblais et leur mode de gestion (stockage, remblaiement). Ces résidus renferment de grandes quantités de charbons de bois, ultimes traces des milliers de brasiers qui ont permis d'exploiter la galène argentifère (sulfure de plomb titrant 0,15 % d'argent). L'exiguïté du contexte archéologique et l'ampleur des remblais de taille au feu ont nécessité la mise en place d'un protocole de prélèvement adapté. L'étude de ces dépôts, combinée avec l'analyse archéologique des ouvrages et avec l'approche sédimentologique des remblais, permet de reconstituer le territoire d'approvisionnement en bois de feu des mineurs. Les premiers diagrammes autorisent des interprétations en termes de gestion et de modes d'adaptation aux disponibilités environnementales. Cette contribution fait état de travaux préliminaires menés dans le cadre un Diplôme d'Etudes Approfondies sur les protoindustries et la forêt dans la haute vallée de la Durance au Moyen Âge et d'une fouille archéologique programmée.

MOTS-CLÉS: mine, Moyen Âge, abattage au feu, charbons résiduels, représentativité, paléoécologie

ZUSAMMENFASSUNG: Die mittelalterlichen Bergwerksanlagen des Fournel im Département Hautes-Alpes (France) bilden einen ungewöhnlichen Rahmen für eine anthrakologische Studie. Die ausgiebige Anwendung von Feuer zur Sprengung eines besonders harten mineralhaltigen Gesteins ging mit Abbaustrategien einher, die den Aufbau der Holzschichtungen, die Verfahrensweise, die Morphologie des Abraums und deren Entsorgung (Halde, Zuschüttung) beeinflussten. Die Brandrückstände enthalten große Mengen von Holzkohle, Reste tausender Brandherde, die zum Abbau des silberhaltigen Bleierz (zu 0.15% silberhaltiger Bleiglanz) eingesetzt wurden. Die beschränkten Möglichkeiten der archäologischen Untersuchung und der Umfang der durch die Feuersetzung angefallenen Rückstände machten eine methodische Absicherung der Probenentnahme erforderlich. Die Analyse der Rückstände im Verband mit der archäologischen Untersuchung der Holzaufbauten und der sedimentologischen Erfassung des Abraums ermöglicht es, das geographische Umfeld der Holzbeschaffung durch die Bergleute für die Feuersetzungen zu rekonstruieren. Die ersten Diagramme lassen Deutungen zum Rohstoffhaushalt und zur Anpassung an die Umweltbedingungen zu. Unser Beitrag stellt erste Ergebnisse von Vorarbeiten vor, die im Rahmen eines Dissertationsvorhabens über die frühindustrielle Nutzung des Waldes im oberen Durancetal im Mittelalter mit einem Grabungsprogramm durchgeführt wurden.

STICHWORTE: Bergbau, Mittelalter, Feuersetzen, Brandrückstände, Holzkohle, Paläoökologie, exemplarische Studie

INTRODUCTION

Before the invention of "modern" fuel, the use of explosives and later material for underground planning, (cast iron canalisation, railway tracks for example), an almost organic relation existed between the mine and the forest. All activities leading to the operating chain of metal production, consume wood. One after the other or simultaneously, they are at one moment or another of history, accused of being responsible for enormous destruction of forests and are therefore subjected to strict regulation. The ancient mining method of fire-setting has long been the source of pessimistic descriptions concerning precocious deforestation near a mine site. During the nineteenth century the deforestation of mountains is partly imputed to this method called archaic, but still largely practised at that time in the Hartz mines in Germany and also at Kongsberg in Norway (BERG 1992). These regions are in fact well known for their inexhaustible forest resources, but are they not guardians of a rather efficient replanting policy? Actually, no reliable figures are available to feed this argument and show the theory of a massive and irreversible "mining deforestation". In spite of these gaps, we are obliged to consider the relation that exists between certain extraction sites and the particularly denuded areas such as the Brandes plateau in the Oisans region (French Alps).

The abundance of charcoal conserved in the underground backfill and in the waste heaps of the Fournel mines (L'Argentière-la-Bessée) authorises a profound charcoal study. They synthesise an intensive consumption of wood that stretches over at least four centuries. Thus it is possible to detect in first anthracological diagrams a behavioural evolution of supplies in firewood and to make an estimation of the available ligneous biomass. However, to ensure operational lines of work it has been necessary to develop methods and strategies proper to this original archaeological programme. A notable problem was the palaeological representativeness of charcoal issuing from an extraction technology.

STUDY FRAMEWORK

Geography, Biogeography and Geology

One part of the ancient mining works lies at the bottom of the enclosed valley of the Fournel which forms a gorge 1 km in length. Upstream, it emerges into the glacial valley of the Alp Martin situated on the Eastern face of the Ecrin massif between the intermediary and internal Alps. Its catchment area belongs to the hydrographic basin of the High Durance. Downstream, the gorges open progressively and emerge into the Durance valley (Fig. 1). Above the gorges, on a steep wooded versant,

situated on the right bank, lie some ancient crumbling works. On the right bank, a very steep slope, prolonged by an incline more regular and occupied by the hamlet of "l'Eyssailon" at 1100 m of altitude. It continues thus until the summit of the "Têtes" which culminates at 2000 m of altitude. Downstream, this incline is brusquely interrupted by a rocky shoulder of quartzites, lightly cut by several thalwegs. The ancient works and modern research are situated in a level variation of 800 m (Fig. 2) (ANCEL ET AL. IN PRESS a).

This region is characterised by terraced vegetation and a strong contrast "ubac"/"adret". In the "adret", the bottom of the versant is characterized by grassy pre-steppic levels of *Juniperus* and *Lavandula* (900-1200 m alt.). A rich shrubby vegetation is developing in rough land at the edges of meadows and terraces (*Berberis vulgaris*, *Prunus spinosa*, *Cytisus*, *Cornus sanguinea*, *Crataegus*, *Fraxinus excelsior*). Forests of hardwood and shrubs grow at the bottom of the versants of the "ubac" and on the outskirts of the Fournel (*Corylus avellana*, *Sorbus aucuparia*, *Populus tremula*, *Fraxinus excelsior*). Then the mountain shelves stretch up to 1500-1800 m of altitude. The "adret" is characterized by a heliophilous forest of *Pinus sylvestris*, the heathland with *Juniperus* in the warm and sunny parts, and hardwoods at the beginning of the valley (*Fraxinus excelsior*, *Acer pseudoplatanus*, *Rosa*). In the "ubac", the extension of the pinewoods is limited. The ancient pastureland is rapidly surmounted by larch plantations and thickets of *Sorbus aucuparia*. In the valley, sub-mediterranean influences raise the limits of the mountain shelf to the "ubac" around 1600 m high and at the "adret" up to 1800 m. The humid forests exposed to the North are composed of fir plantations of *Abies alba* mixed *Larix decidua*. The subalpine shelf reaches up to 2000-2200 m in height. It is notable essentially for its larch plantations in the meadows at the lower limit and the rhodoraie on the upper limit (MEYER 1981, RAMEAU ET AL. 1993).

From a geological point of view, the mine is situated in the Briançonnais zone of the Alpine massif. From East to West, the ground is schematically composed of carboniferous sandstone, of permian conglomerates (Verrucano facies), of quartzites and of triassic limestone. They have been uplifted vertically by the thrust and are dislocated by numerous faults. There exist several seams of the Eocene to Oligocene periods, enclosed in quartzites. They are cut in panels orientated North-East/South-West, sub-vertical or inclined toward the South-East, at 15 to 50°. Their length varies from 0.50 m up to 7 or 8 m. The predominant ore is argentiferous galena. The matrix is composed of quartz and barytine. This ore is more or less concentrated. The richest part shows between 10 and 30%. It was mined exclusively during the Medieval epoch then privileged by the Moderns (ANCEL ET AL. IN PRESS a).

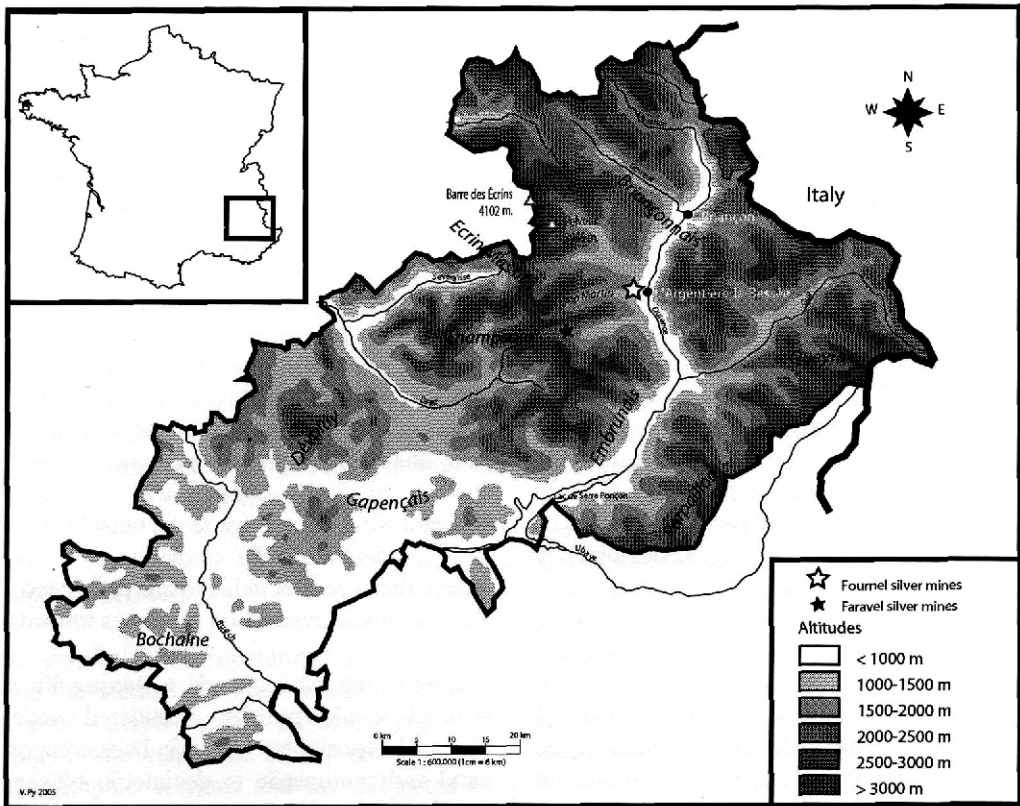


Figure 1. Localisation of the Fournel and Faravel mines (Hautes-Alpes, France).

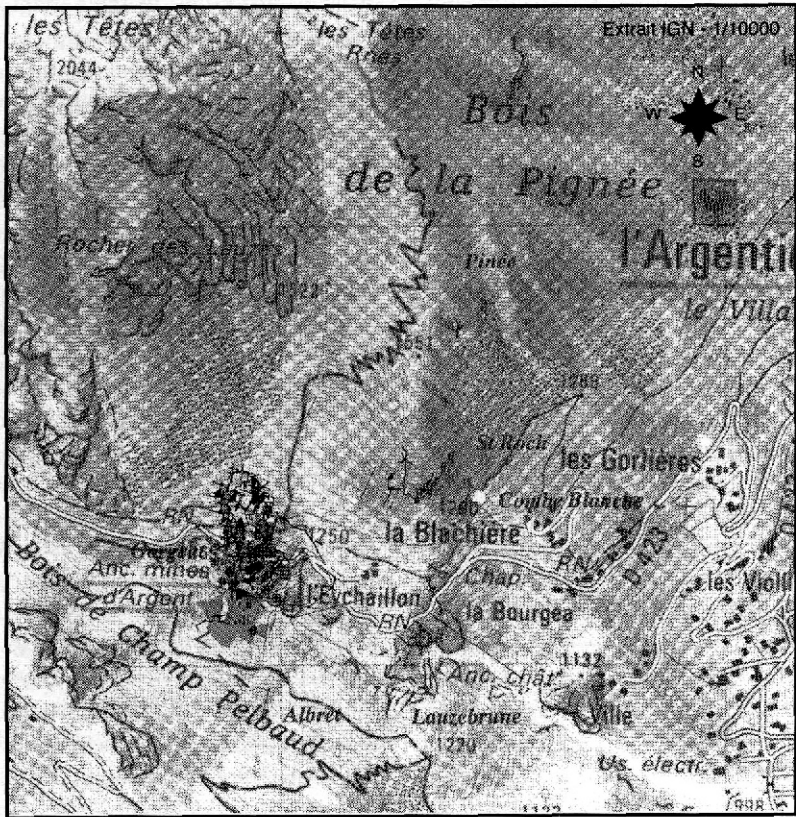


Figure 2. Localisation of the medieval workings (Extrait IGN 1/10000, B. Ancel 2004).

Archaeological context

The prospections¹ conducted on the rock outcrops show numerous traces of ancient workings began as open cast exploitations for over 4000 m² (ANCEL 1998a). The medieval workings are situated in the Fournel gorges, in the localities of "Gorgeat" and "Lauzebrune" and, on the "adret" slope, at "Saint Roch", "Comble Blanche", the "Rouille" and the "Pinée". They are composed of small sized galleries and firesetting sites mostly backfilled. They form five principal sites quite distinct, which reach in to over 100 m from the face (FIG. 2). According to approximate estimations, the miners displaced a total of 20000 m² of mineralisation. This is a considerable volume to have excavated.

Firesetting was initially used to mine quartzites, the surrounding rock being for the most part very hard. The use of this technique is characterised archaeologically by rounded vaults covered in soot and by rich charcoal deposits in the backfill (ANCEL *ET AL.* IN PRESS b). Owing to the size and good state of conservation of the site, the archaeologists were able to elaborate interpretations of the operational dynamics and characterise the general organisation of the underground site. The steepness of the place did not constitute a real handicap for this exploitation based on manual work and carriage on the backs of men and mules. The strong level variation facilitated vertical development of the sites, evacuation of used air by thermic aspiration and drainage of infiltrated water by gravitational flow. The sites marry well the geometry of the stratum with the works assistance, developed as systematic control of problems (ANCEL 1998a, b, 2000).

METHODS AND STRATEGIES: SEVERAL VIEWPOINTS

The exiguity of the medieval workings (caving access), the stratigraphic complexity of backfills and the relatively unknown uses of wood in firesetting, necessitated putting into place a pluridisciplinary approach. Study of the combustible requires an experimental approach to characterise notably properties of the wood, its burning qualities, combustion process in a semi-closed situation (air currents) and charcoal fragmentation. Their macro- and microscopic analysis permitted to build up the basis of a collection of references on the state of the wood and the traces of burning². Concurrently, field study coupled with a sedimentologic approach is realised on the backfill, product of the accumulation of poor or sterile wastes, issued directly or indirectly from firesetting.

Archaeological approach

For the last twenty years, anthracological work has shown the major importance of sampling archaeological charcoal

to find information exhaustively (quantitative) and obtain a representative corpus (qualitative) (CHABAL 1982, 1988, 1991, 1997, HEINZ 1988, BADAL GARCIA 1990). The method can be applied to the mining context following particular modalities.

In the zones near the open cast sites, the ancient backfill is masked by gravel more or less infiltrated by sand mixed with earth. Access can require an important work of cleaning and clearing. On top of this, these zones have been affected by exploitation attempts in the nineteenth century. The wastes mostly untouched are often lying in remote and inaccessible parts of the mine. They have been stocked by the miners, who reserved circulation passages and, abandoned once the vein panned out. This rigorous method of deads management avoided the long and difficult work of carriage to the outside. To obtain deposits best characterizing the extraction of a cavity, the works where the access is delicate are privileged. They exclude the systematic evacuation of wastes towards the exterior.

Excepting the mining heads, a plotting dig with a squaring method would not be considered underground. The charcoal deposits are sealed in beds composed of gravels, sand and centimetric to decimetric blocks, too unstable for excavation. The adopted strategy consists of effecting successive stratigraphic sections in the trenches (opencast) or the access works or, enormous transversal cuts of the whole site. They are photographed, plotted and described in detail according to their granulometry, the inclusions and their colour.

This method brings out anthracological samples in every characterized layer, renewed in every successive cut (1 to 2 m of interval) or on the whole length of the big transversal cuts. Spatial analysis of the charcoal deposits is therefore possible. From 10 to 30 litres of firesetting waste can be taken from each layer, depending on their richness. This method permits acquisition of a rigorous sample, representative of the statistic population of a deposit. The difficulties of moving a load imposes sifting *in situ* where floatation is excluded. The humidity of the waste necessitates the uses of a column of sifter screens 8-4 mm to evacuate the bigger elements and avoid obstruction of the finer mesh. The material thus sifted is integrally recovered. It is dried then classed in a laboratory. A second sifting using water can be necessary for the dirtier wastes. The charcoals smaller than 4 mm are excluded from the study because they come from the fragmentation of the bigger pieces. The fragments bigger than 4 mm offer the same proportion between types than the charcoals composed between 0.5 and 3 mm and their floristic content does not seem different (BADAL-GARCIA 1990, CHABAL 1997: 37).

A paleoecological and ethnobotanical approach must be envisaged in the long term to perceive the

significant changes and the installation of techniques. The anthracological sampling must be realised on the scale of the site (gallery, hall) but also to the scale of the network. This imperative implies a tight cooperation with mining archaeology which seeks to determine a relative chronology with the works. Several are refilled with tons of waste and disfigured by the resumption of work in the nineteenth century. Thus, the interpretation of the operating dynamic is incomplete. Considering the scale of the site, the modalities of management of wastes as the mining advanced are difficult to perceive (ANCEL IN PRESS). Radiocarbon dating proposes a bracket still too large and time passed between each deposit is hypothetic. A multiplication of radiocarbon dating within the same working and their comparison with sedimentological statistics, could furnish the key to the interpretation.

Sedimentology approach

To apprehend precisely the operating dynamic and management of the steriles by the miners, Christophe Marconnet proposes a new method based on protocols of sedimentology³. The sand and bigger elements are sampled in stratigraphic sections and are subjected to granulometric classement and macroscopic analysis. A similar study is conducted on the residues set apart in the materials obtained during firesetting experiments (Fournel mine). This permitted to identify granulometric characters proper to each stage of the firesetting and the factors susceptible to modification (MARCONNET 1994). The results of analysis accomplished on the archaeological samples are more heterogeneous and diversified. They are without a doubt allied to the firesettings realised in varying rock contexts. But this variety of granulometric facies underlines especially the existence of an operating model more complex than the experimental protocol, comprising the pick up, transport, stockage and sorting stages, evidenced by the stratigraphy. The comparative study of these residus of different origins, permits progression in the comprehension of the firesetting techniques.

Anthracological approach

Underground wastes

The layers of wastes containing charcoal inclusions interpolate themselves with "clear" layers. The charcoals are found either in a dispersed form with small sized fragments (4-6 mm) hardly visible to the naked eye and spread in a homogeneous way in the layer, or under a concentrated form with bigger centrimetric fragments. Easily accessible, they were selected essentially by archaeologists to meet the quantity necessary for radiocarbon analysis. They were subjected to sampling to date the exploitation of different networks.

In spite of the "choice" induced by the selection of the bigger elements to the detriment of the finer fractions, these charcoals were subjected to a first experimental analysis (sample portion of type 1). The total being, 1079 fragments selected in the areas of "Vieux Travaux" (Gorgeat), of "Saint Roch", of "Lauzebrune", of the "Pinée" and the "Combe Blanche" have revealed three different taxa: *Larix-Picea* (cf. *Larix*), *Pinus* type *P. sylvestris* and *Abies* sp. *Larix-Picea* appear to be used in priority. Nevertheless, some remarkable variations appear as in the diagram of "Saint Roch" where *Abies* sp. shows 60.5% of relative frequencies against 39.5% for *Larix-Picea* and, in the case of "Vieux Travaux" where *Pinus* type *P. sylvestris* is dominant in two sequences of the diagram (FIG. 3). In the absence of a preliminary methodological reflection, these inversions of the dominant taxa (or secondary in the case of *Abies* sp.) could be interpreted as a change in the wood supply modalities, but, they are probably the truncated image of backfill of odd logs or the spreading of centres of woodcutting rarely touched. A second campaign of sampling was therefore begun following the modalities presented earlier and targetting the dispersed stratified deposits which could offer a good synthetic effect of the combustible used.

A total of over 1500 new fragments have been subjected to preliminary anthracological study. They revealed very clear refinement of proportions between the majority of taxa and a light opening of a floristic spectrum with the appearance of hardwoods of which the proportions were anecdotal (FIG. 4). *Pinus* type *P. sylvestris* poorly represented or over represented in the samplings of "type 1", constitute in the samples of "type 2", 1/10 to 1/3 of the combustible put to work for the firesetting. Under this title, the sequence of "Lauzebrune", dated eleventh century, is very significant. In the sample E28 (type 1), *Larix-Picea* totals 100% of the relative frequencies whereas in the samples 2P2 and 1P1 (type 2) *Pinus* type *P. sylvestris* reach 22.6% and new taxa appear: *Fraxinus* sp. and *Acer* sp.

In the locality of "Vieux Travaux", a "test" sample realised from a stratigraphic section in a waste heap offered a frequency distribution quite homogeneous in the four identified layers. However, the frequency intervals between the different taxa do not overlap. A X^2 test realised from the relative frequencies of different taxa in each sample show a highly significant difference of the distribution of frequencies in the four layers. According to the calculations of contributions *a posteriori*, the samples 17 and 19 are responsible for the high value of the X^2 test. It seems that the number of fragments analysed (50) in the sample 17 have influenced the proportions between the *Pinus* type *P. sylvestris* and *Larix-Picea*. In return, the sample 19 counts 100 fragments, a consequent amount compared to the little portion of sampled layers. This established fact leads to the problem of the optimal amount necessary in each layer.

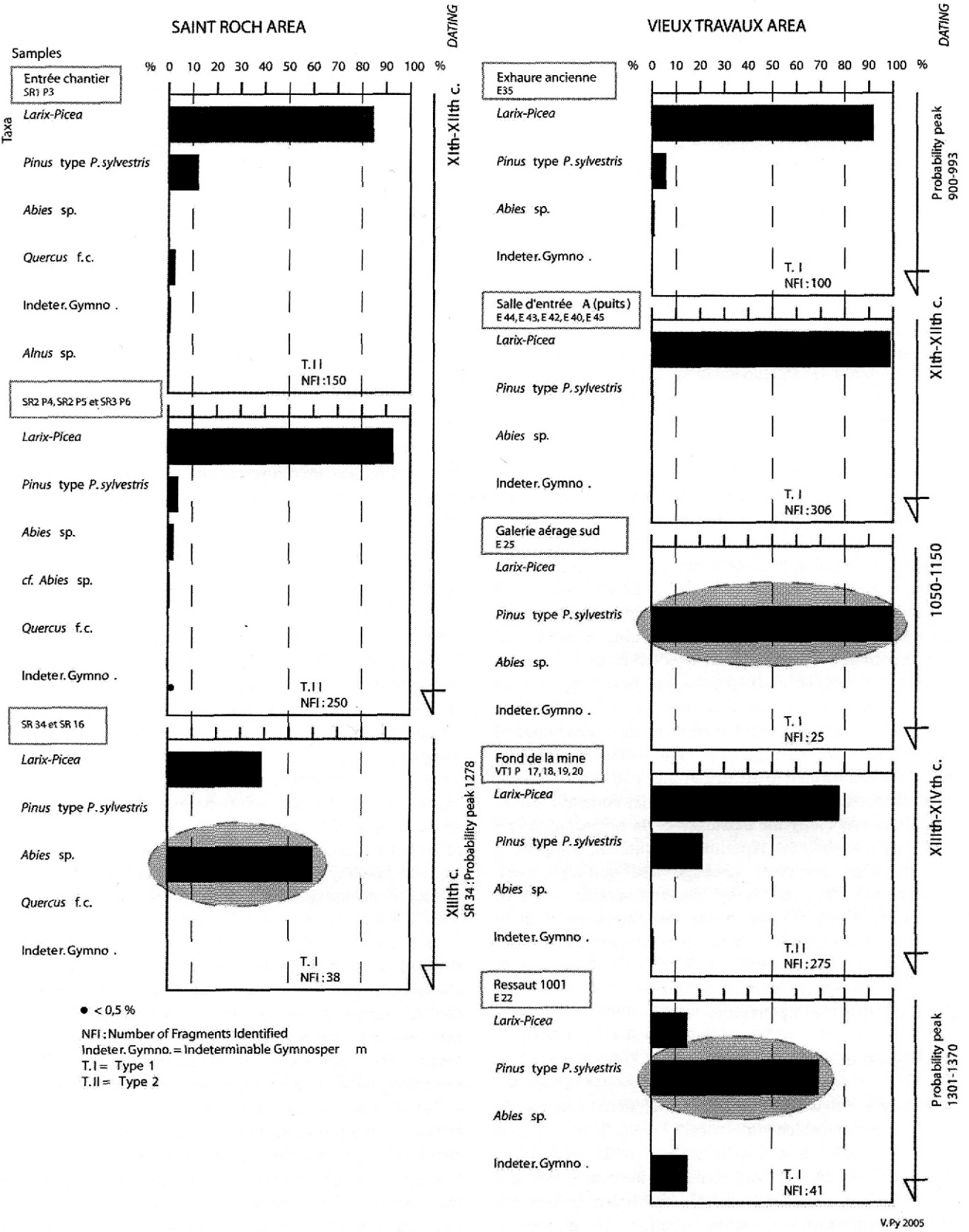


Figure 3. Significant inversions of the dominant taxa in samples “type 1”: Example of anthracological sequences of “Saint Roch” and “Vieux Travaux”.

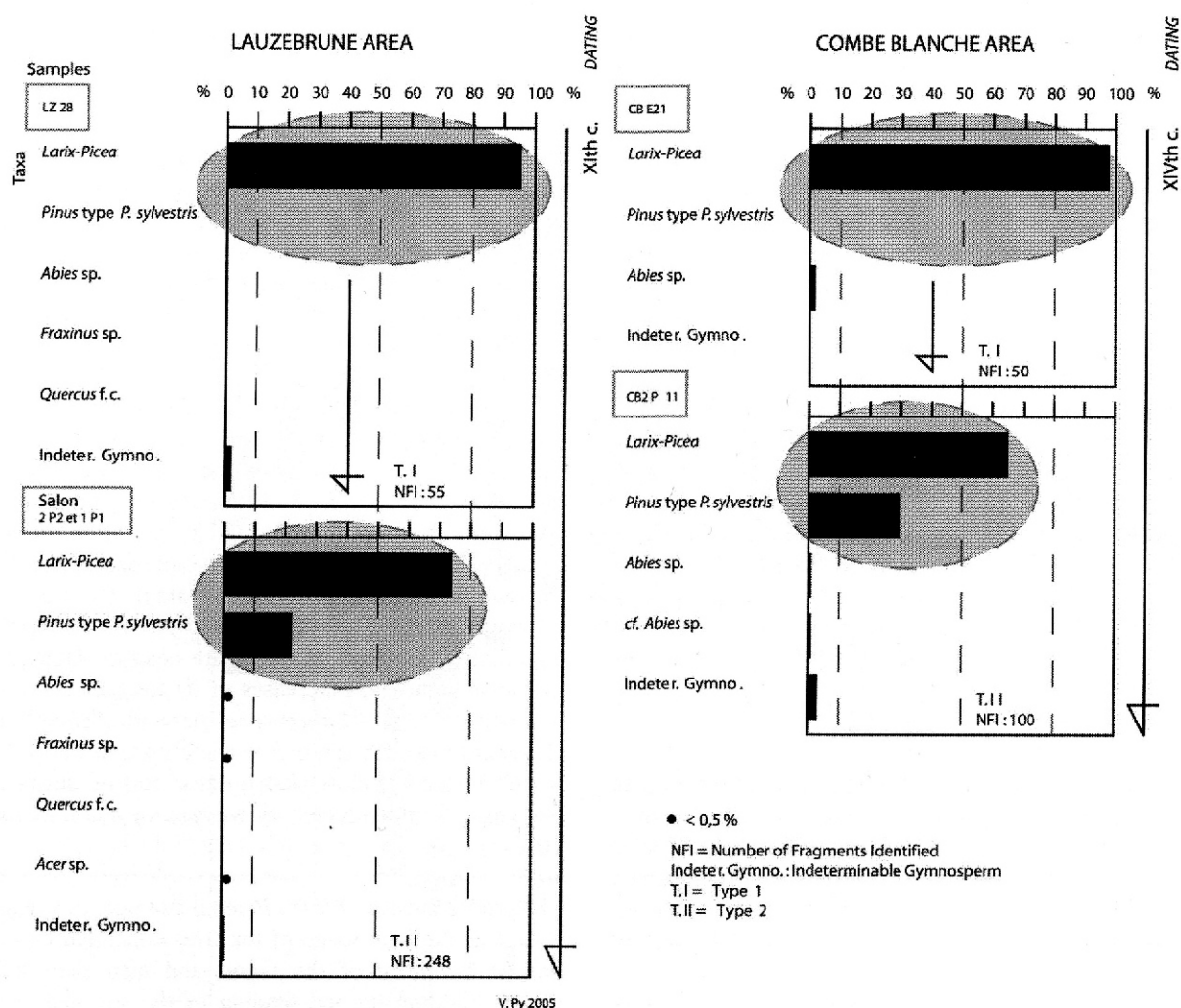


Figure 4. Enlargement of the spectre and refinement of the proportions between the dominant taxa with type 2 sampling. Examples from the anthracological sequences from Lauzebrune and Combe Blanche sectors.

The number of taxa potentially present is too reduced in this type of deposit to have recourse to the effort-yield stage. With a random sampling of the fragments, a frequent variety has more chance to surface than a rarer one. It is therefore important to sample a consequent amount to come up with a less common variety and hope to obtain refined proportions between taxa. In this specific case, a minimum amount of 50 to 100 charcoals each layer in a same stratigraphic section is therefore largely accurate.

The wasteheap potential

The totality of medieval exploitation remains, visible on the surface, is tied to the extraction of ore. It concerns the open cast sites, the orifices of tunnels and the vast pile of waste characteristic of a mining scheme: the heaps. They are still well apparent on the slopes of "Saint Roch", of the "Rouille" and of the "Pinée", but their morphology is considerably altered by reason of erosion (ANCEL 1998a,b).

West of "Combe Blanche", extends a vast modern heap composed of very fine waste of whitish colour, characteristic of quartzites and barytine. They cover older rejects and mask the presumed entrances of "Saint Roch". On the Eastern versant which dominates the town of L'Argentière, the quartzites are outcropped on the scree summits. The "rust" colour which affects certain flows signals the presence of rubified matrix. On the south side, the most important flow is topped by a plateau of waste (large shoulder). To the north of "Rouille", on the right hand side of the big scree, the principal vein has been subjected to an open cast scrape on 1600 m². The summit of the layer is recut by a mineralised fault which has been partly exploited by fire. Important quantities of residual charcoal are spread on the ground. In the gorges, the rejects of deads carried by colluvial action and by flooding of the torrents have practically disappeared.

These important spreads of sand and gravel are formed

by the accumulation of successive scrapings of the rock. They do not contain all the wastes of the miners who searched obstinately to stock them in the mine to reduce to the maximum of the work of evacuating them to the surface. The compiled analysis of the surface waste and the underground backfill is therefore complimentary. It seems pertinent to evaluate the statistical frequency of charcoals contained in these deposits and to test their anthracological potentiel. The stratigraphy corresponds in shape to the dip of the versant and is composed of alternate layers of sandy matrix, including gravel and small stones of centimetric to decimetric size and more rarely of blocks.

The samples taken in layers 2 and 3 of the sampling opened in the "white heap" gave good results with 30 litres of waste per layer. In total, the analysis of more than 600 fragments offers good broadening of floristic spectrum with the appearance of new taxa such as *Juniperus* sp., *Laburnum-Cytisus* and *Ulmus* sp. (FIG. 5). The degree of effort-production tends to stabilise beginning at 250 charcoals analysed. One approaches the normal standards of the classical archaeological context (CHABAL 1997).

A stratigraphic section of 3 m in length, realised in the surface waste at the entry of the "Pinée" network, permitted a second sample "test" in a coal layer sealed between the "clean" layers. 40 litres of waste sampled gave 265 charcoals. In this case, the degree effort-production tends to stabilise at the 150-200 level of charcoal analysed.

The minimum amount of charcoals to sample in the deposits of "wasteheap type" can be evaluated at least 200 fragments by layer to attain the level. Anyway, as several species totalise almost all the frequencies (*Larix-Picea* et *Pinus* type *P. sylvestris*), a superior number can be necessary for a maximal refinement of the proportions of varieties between themselves.

The heap which apparently offer a good effect of synthesis of the combustible burnt (broadening of the floristic spectrum) are difficult to date and the possibilities of interpretation in terms of economy of wood are limited. Indeed, these vast heaps of waste have they been formed in one year, or in a dozen or more? A second problem is the "levelling" of the spectrum and the impossibility to detect the punctual variations or cycles which could reveal the modalities of management, the techniques and the evolution of the forest landscape. The variations between dominant taxa are diluted in the general mass of combustible used over a period difficult to evaluate.

A sampling on a larger portion of waste would be necessary along with those obtained in the corresponding exploitation zone.

FIRST RESULTS AND INTERPRETATIONS

This preliminary study was realised on a total of 2429 charcoals spread over the type 1 and type 2 samples.

Despite the truncated character of the samples of type 1, data is integrated in the anthracological diagrams so as to complete provisionally certain chronological sequences comprised between the tenth and fourteenth centuries (FIG. 5). From the radiocarbon datings and the analysis of the operating dynamic, a relative chronology of the samplings is proposed.

The general diagram reveals the absolute dominance of taxa belonging to the arboreal strata. *Larix-Picea* is very prominent in all the sequences, but *Pinus* type *P. sylvestris* overtakes it in the fourteenth century (end thirteenth-beginning fourteenth century?) in the portions of the "Combe Blanche" network and in a portion of the "Vieux Travaux" network (bottom of the mine). The frequencies of *Pinus* type *P. sylvestris* are weak in the workings exploited in the tenth to thirteenth century. There are all the same significant increases of its frequencies, notably in a portion of the "Lauzebrune" network ("salon") dated eleventh to twelfth century and in a portion of the "Saint Roch" network (schist shaft), dated end of thirteenth to beginning fourteenth century where they attain more than 20% (FIG. 5).

The predominance of *larix-Picea* is not tied to a technical choice as the heat value of the fires depended especially on the humidity of the wood and also their calibre, on the building up and tending of the fire and also the structure of the rock being mined. The anthracological analysis of the residual of firesetting in the antique mine of Hautech (Pyrenees) confirms this hypothesis. They present a large range of varieties used in firesetting: *Corylus avellana*, *Fagus sylvatica*, *Quercus* deciduous, *Prunus*, *Populus* (DUBOIS 1996: 39). The miners exploit in priority the varieties present in abundance in their local environnement, but this notion of proximity must be nuanced. It can mean the immediate neighbourhood or available woods near hand, but not necessarily situated in direct proximity to the mine. They could adapt the proprieties of the wood according to technical constraints such as varying the humidity level and also the size of logs (or faggots). Archaeological digs at the entry to the gallery of "Saint Roch" have revealed a work place set aside for the splitting and preparation of wood characterized by the numerous wood chips.

At the Fournel, the mines are situated between hilly shelves and the mountain, the growing area of *Pinus sylvestris*, moors with *Juniperus* and to a lesser degree *Quercus pubescens*. According to the diagrams, the forest exploited by the miners is composed essentially of *Larix-Picea*. The doubts associated with the reconnaissance of larch

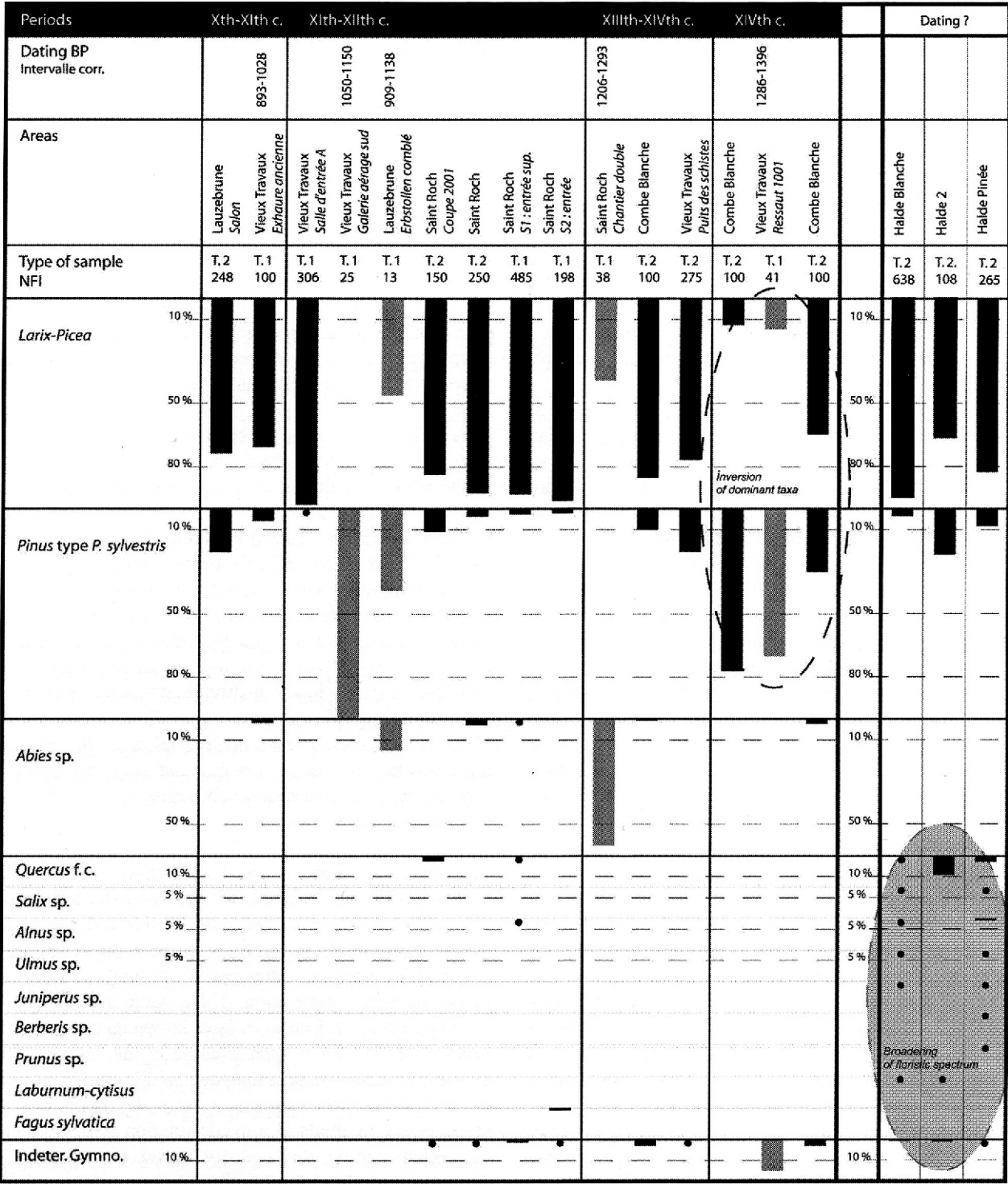


Figure 5. General anthracological diagram of the Fournel mine.

(*Larix decidua*) and of the spruce (*Picea abies*), noted *Larix-Picea*, repose on the characteristics belonging to the anatomy of these two species, difficult to distinguish by

means of compared anatomy. However, their respective ecology coupled with recognition of the diagnostic criteria of the larch, permits to lean towards *Larix* (TALON 1997).

Nowadays this variety is often in a pioneer phase and in false climax in the superior mountain shelves or in the subalpine inferior shelf in the locality of firs and spruces. The miners exploitation territory appears to be oriented towards the forests at the superior limit of the mountain level (to the "ubac") and in the subalpine larch localities. This constatation is confirmed by the traditional practises of forest exploitation where it is preferred to clear the higher wood towards the bottom of the mountain. This provisioning can also correspond to the relative absence of combustible in the mountainous forests because *Pinus* type *P. sylvestris* is of generally feeble frequency. Its significant augmentation in the diagram of "Lauzebrune" can reflect a variation of the limits of the supply territory, reorientated punctually towards the mountain forests of the Southerly exposed versants.

The low frequencies of *Abies* projects the image of a pine locality in a colonisation phase, in the wooded massive of the "ubac". The high frequencies registered at "Saint Roch" are related to an over representation of the taxa because the sample is localised and not representative. It should be at this time excluded from the paleoecological interpretation. The hypothesis of a degraded pine colony as early as the tenth century must be considered with much reserve. The feeble frequency of *Abies* could eventually correspond to the rigorous management of this species of first choice. In the Pyrenees, it has been subjected to a voluntary policy of conservation for workable wood: these are the "bèdes" or "bedats" of which the locality is totally independant of natural conditions (DAVASSE 2000). In the light of textual studies the conclusions are similar for the anthracological diagrams of the Catalonian Pyrenees (IZARD 1999). According to the regressive study of the high alpine texts, a policy of strict management of the pine localities has not yet been remarked. In the 18th century this variety was exploited in the same manner as pine and the larch for workable wood. This significant augmentation of the frequency of *Pinus* type *P. sylvestris* at the end of the 13th and beginning of the 14th century can reveal a localised variation in the time of supply strategies of wood for the miners. With the necessary reserves towards the interpretation of preliminary data, this modification of frequencies of dominant taxa can correspond to a new phase of exploitation of the mine after a period of non production, long enough to permit the regeneration of the pine forest, very dynamic. A second hypothesis, shows the problem of a very distinct variation of the area of exploitation which before was inclined towards high larch growths and reorientated towards forests of a dry mountainous type where *Pinus* type *P. sylvestris* could have been reserved at the expense of *Larix-Picea* higher in altitude.

Quercus pubescens, leader of the supramediterranean forest, does not appear, or at least very little in the anthracological diagrams (*Quercus deciduous*). This feeble representivity probably characterizes its reduced place

in the ligneferous biomass available to the miners. The samples observed show narrow growth rings, characteristic of a wood which has developed in a xeric environnement ("adret"). With relative frequencies which reach the height of 2% at "Saint Roch" and of 9.3% in the "halde 2" sampling and in spite of limits tied to poor representivity of certain samples (type 1), the oak growth appears largely decapitated, at least since the 10th-11th centuries. It has given way to *Pinus* type *P. sylvestris*, a pioneering variety in the mountain and dry sub mountain forests. This interpretation implies a strong anthropisation of the versants at an early period. It may be the indirect reflection of a precocious apparition of "blaches" and oak plantations towards the 10th-11th centuries, perceptible in the written sources. This observation goes in the direction of the development of vinyards at this epoch (POGNEAUX 2001).

This early data permits a schematical outline of the types of forest management practised to obtain wood. As early as the 10th-11th centuries, the supply area opens in the high mountains forests knowing that the optimal localisation of *Larix* is actually situated between 1750 and 2100 m of altitude. This reflects probably a choice related to the forest availabilities and the accessibility of wooded areas for the laying of haul roads. *Pinus* type *P. sylvestris* appears to have been exploited more episodically with a significant peak at the end of the 13th beginning of 14th century. This variety develops generally lower in altitude. It is actually localised on the limestone massifs of the "adret" between 1200 and 1700 m of altitude *Pinus uncinata* takes up the relay (at the moment, growths of this pine are very localised). Its acquisition reflects an area which is punctually reorientated towards the "adret" massifs.

The diagrams show a wood collection which is not monospecific but adapted to the availabilities which may vary according to the state of wooded areas. The woodcutters could cut the trees in the areas (clearing or selective?) abandoned after partial or total deforestation to permit their regeneration. These same areas could be re-exploited several decades later knowing that about 50 years is needed for a larch situated in the superior limit of the forest to realize a diameter of 20 cm (PETITCOLAS ET AL. 1997). One can easily emit the hypothesis of management methods in a cyclic rotation form. Actually, no reglementation destined for wood management of the mining needs of the Middle Ages permits to validate a such hypothesis. Anyway, it is difficult to agree with the "traditional" vision of the medieval forest being attacked from all sides by a population unconcerned by its regeneration (SCLAFERT 1933).

CONCLUSION

These first results show the pertinence of an anthracological approach in a mining context, validated

notably by the ecological coherence of the diagrams. It permits to obtain new information on the methods concerning forest exploitation developed "upstream" of mining extraction. Above and beyond a strictly environmental aspect, it opens perspectives of research on the history of forest economy, valorisation of natural resources and operating systems of combustible material for alimentation of protoindustrial activities in the Middle Ages. From a paleoecological point of view, this brings to light the South-alpine medieval mountain forest still little known to environmentalists who until now tended to concentrate on the problem of altitudinal variations of the superior limit of the "dense" arborescent strata and the impact of the first agropastoral activities in high mountain regions (TALON 1996). Finally, it brings in some anchor points to study more finely the history of the larch and its expansion which is in close relation with the development of anthropical activities. Its management for the supply of firewood appears evident in the case of the Fournel mines.

This reflection constitutes a basis of theoric reconstruction of the evolution of an industrial landscape in the 10th-14th centuries. It implies looking from different angles at the paleoenvironmental approaches to varied species (palynology, dendochronology, analysis of lead) and on the archaeological data which characterises the structure and places.

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¹ The ancient silver mines of Fournel are, since 1992, the centre of an archaeological dig directed by Bruno Ancel and benefit concurrently from an aid programme of heritage development led by the town council of l'Argentière-la-Bessée.

² See contribution by Bruno Ancel and Vanessa Py in this book.

³ The method of C. Marconnet is presented in the acts of the colloquium of Châteaudouble 2000, in press.

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